



## General Training On Methodologies For Geological Disposal in North America

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### Site Screening and Selection



Michael Voegele  
Senior Technical Advisor  
Bechtel SAIC Company, LLC  
e-mail: michael\_voegele@ymp.gov  
Telephone: 1-702-295-5520

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### Outline

- **General Structure of Siting Process**
  - National Mandates
  - Performance Criteria
  - Regulations
  - Siting Guidance
- **Illustrative Examples of Elements of Screening Structure**
- **Brief Overview of Development of Disposal Programs in the United States**
- **Site Selection in the United States; Yucca Mountain Screening Under The NWPA**  
**Yucca Mountain Site Suitability Evaluation**

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### National Mandates

#### Set National Policy

- Define responsibilities, schedules, and process to be followed
- Define authorities
- Dictate specific factors to be considered
- Dictate specific sites to be considered or avoided
- Address societal concerns
  - NIMBY (NIMEY) is prevalent
  - Most programs have adopted policies of intergenerational equity, and fairness
  - Volunteer sites may be sought
  - Special compensation may be offered

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### Performance Criteria

- Establish standards that sites must meet to be considered for a repository
  - Could be set in legislation or by a regulatory authority
- General international consensus on appropriate risk levels
  - Significantly lower than other levels of risk society accepts
  - Have quantitative and qualitative aspects
  - Time periods of regulation vary
- Generally consider engineered as well as natural features

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### Regulations

- Regulatory agencies could be tasked with oversight, licensing, or permitting
- Regulatory topics could address screening, as well as repository performance
- Regulations could specify formal process for permitting, licensing, or approval

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### Siting Guidance

- Implementing Agencies may specify detailed process methodologies for screening and selection
  - Formal process; should be public and invite participation
  - Observers should be able to understand the meaning of the different steps of the process
  - Regional geological character impacts ability to compare sites
- Comparative in nature; successively reduce number of sites under consideration
- Culminates in National decision to move forward into licensing or permitting phases

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### National Mandates - Examples

- **Nuclear Waste Policy Act (US, 1982)**
  - National Screening
- **Nuclear Waste Policy Amendments Act (US, 1987)**
  - Yucca Mountain
- **Energy Policy Act (US, 1992)**
  - Yucca Mountain standards
- **Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act (US, 1980)**
  - WIPP authorized
- **WIPP Land Withdrawal Act (US, 1992)**
  - EPA regulations, no HLW or SNF
- **Joint Statement (Canada, 1981)**
  - Concept development
- **Nuclear Waste Fuel Act (Canada, 2002)**
  - Path forward

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### Performance Criteria - Examples

- **Radiation Protection Principles for the Disposal of Solid Radioactive Wastes (ICRP, 1985)**
- **Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes (40 CFR Part 91, US EPA, 1985 [remanded], 1993 )**
  - Population standard; cumulative release to accessible environment
  - Two part standard; probability of event occurrence
  - Ground water protection and human intrusion addressed
- **Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV (40 CFR Part197, US EPA, 2001)**
  - Individual protection standard; dose to individual from releases from the repository at Yucca Mountain
  - Lifestyle of Reasonably Maximally Exposed Individual specified
  - Ground water protection and human intrusion addressed

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### Regulations - Examples

- **Disposal of High Level Radioactive Wastes in Geologic Repositories, (US, 1982, 10 CFR Part 60)**
  - Siting criteria (favorable and potentially adverse conditions); subsystem performance objectives; total system performance assessment
- **Deep Geological Disposal of Nuclear Fuel Waste: Background Information and Regulatory Requirements Regarding the Concept Assessment Phase (Canada, 1985)**
- **Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada (US, 2001, 10 CFR Part 63)**
  - Risk informed, performance based; no subsystem performance objectives; total system performance assessment
- **Criteria for the Certification of and Determination of the Waste Isolation Pilot Plant's Compliance with Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High Level, and Transuranic Wastes (US, 1995 (draft), 1998, 40 CFR 194)**

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### Siting Guidance - Examples

- Site Selection Factors for repositories of Solid High-Level and Alpha-Bearing Wastes in Geological Formations (IAEA, 1977)
- Geological Criteria for Repositories for High Level Radioactive Wastes (US, 1978)
- NWTs Criteria for the Geologic Disposal of Nuclear Wastes, Site Qualification Criteria (US, 1979, 1981)
- General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (US, 1985, 10 CFR Part 960)
- Geological Considerations in Siting a Repository for Underground Disposal of Radioactive Wastes (Canada, 1987)
- General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories; Yucca Mountain Site Suitability Guidelines (US, 2001, 10 CFR Part 963)

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### Disposal Programs in the United States

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### U.S. National Disposal Programs

- **Historical Highlights**
  - First operating commercial reactor (1955); reprocessing
  - National Academy of Sciences [NAS] recommendation for geologic disposal (1957)
  - Investigation of repository facility in salt (Lyons, KS)
  - Formal screening of US salt formations for TRU repository (1973)
  - WIPP site chosen (1975)
  - Nuclear Regulatory Commission [NRC] and Energy Research and Development Administration (later Department of Energy [DOE]) created (1975)
  - Reprocessing stopped
  - National Waste Terminal Storage [NWTs] Program investigated sites throughout the US
  - Previously contaminated sites included
  - State (MN) / Utility lawsuit (1979)
  - Congressional recognition of need to address national problem (1980)

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## Nuclear Waste Policy Act of 1982

### Established U.S. Policy for disposal of commercial spent nuclear fuel

- Responsibilities for EPA, NRC, and DOE
- Funding mechanism
- Provisions for interim storage
- Participation of states and tribes
- Provisions for high-level wastes
- Siting guidelines for selecting and recommending repository sites
- Screening process
  - Two repository programs
  - Site nomination and recommendation; Environmental Assessments
  - Site Characterization; informal consultation with regulator
  - Site Selection; Environmental Impact Statement
  - Presidential recommendation to Congress
  - State Notice of Disapproval
  - Congressional override
  - License Application

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## Crystalline Program Screening



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## NWPA Amendments Act of 1987

### Refocused U.S. Policy for disposal of commercial spent nuclear fuel

- Part of Omnibus Budget Reconciliation Act
- Yucca Mountain selected as single site for characterization
  - Multi-Attribute Utility Analysis
  - Increased oversight and cost
- Work on other first repository program sites and all second repository program sites stopped
- Work on Monitored Retrievable Storage Facility stopped
- EIS provisions essentially left in place
- Created a Negotiator, to seek volunteers for siting

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## Energy Policy Act of 1992

- Directed EPA to promulgate standards for the Yucca Mountain site and to seek input from National Academy of Sciences
  - Maximum effective dose equivalent to individual members of the public
- NAS addressed three questions:
  - Whether a health based standard based upon doses to individual members of the public was reasonable
  - Whether it was reasonable to assume that a system of post closure oversight of the repository could be developed
  - Whether it is possible to make scientifically supportable predictions of the probability that the repository's barriers will be breached as a result of human intrusion over a period of 10,000 years
- Directed NRC to conform its regulation to the new EPA standards
- (DOE concluded it needed to conform its regulation as well)

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## Screening Under The NHPA

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## General Siting Guidelines 10 CFR 960

- Detailed geologic considerations - primary criteria for selecting sites in various geologic media
  - Factors that qualify or disqualify sites from development
    - Valuable natural resources, hydrology, geophysics, seismic activity, and atomic energy defense activities, proximity to water supplies, proximity to populations, effects on rights of water users, and proximity to protected lands (e.g., national parks)
  - Further considerations include
    - Proximity to sites where spent fuel and high-level waste are generated or stored and transportation factors
    - Location in a highly populated area, or adjacent to a 1-square mile area with more than 1,000 people
    - Cost and impact of transportation to the site
    - Various geologic media

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### General Siting Guidelines 10 CFR 960

- **Screening process involved a sequence of 4 decisions:**
  - Identification of potentially acceptable sites
  - Nomination of sites as suitable for characterization
  - Recommendation of sites for characterization
  - Recommendation of a candidate site for development of a repository (after site characterization)
- **Four prioritized system-level guidelines with 20 subordinate technical guidelines:**
  - Postclosure System Guideline
  - Preclosure Radiological Safety System Guideline
  - Environment, Socioeconomics, and Transportation System Guideline
  - Ease and Cost of Siting, Construction, Operation, and Closure System Guideline

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### 10 CFR Part 960 Technical Guidelines

- **Postclosure:**
  - Geohydrology
  - Geochemistry
  - Rock Characteristics
  - Climatic Changes
  - Erosion
  - Dissolution
  - Tectonics
  - Human Interference (Natural Resources, and Site Ownership and Control)
- **Preclosure Radiological Safety**
  - Population Density and Distribution
  - Site Ownership and Control
  - Meteorology
  - Offsite Installations and Operations
- **Environment, Socioeconomics, and Transportation**
  - Environmental Quality
  - Socioeconomic Impacts
  - Transportation
- **Ease and Cost of Siting, Construction, Operation, and Closure**
  - Surface Characteristics
  - Rock Characteristics
  - Hydrology
  - Tectonics

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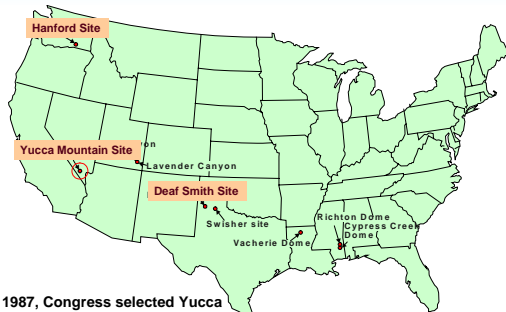
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### DOE Selected 3 Potential Sites (1986)



In 1987, Congress selected Yucca Mountain as the single site to study

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## Yucca Mountain Site Suitability Evaluation

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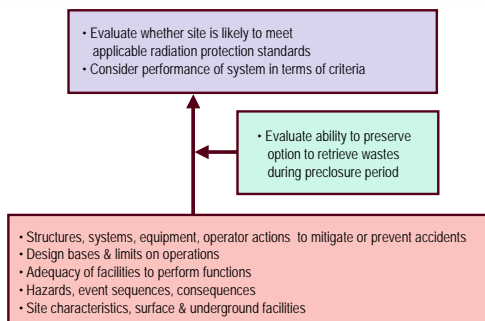
## 10 CFR Part 960 and 10 CFR Part 963

- **10 CFR Part 960 – Siting Guidelines**
  - Implemented the screening provisions of the NWPA through Implementation Guidelines and Technical Guidelines
  - Process to evaluate the sites that the US had been studying under the National Waste Terminal Storage Program
  - Had some level of public acceptance in the process
- **10 CFR Part 963 – Suitability Guidelines**
  - New guidelines needed because of EnPAct
  - Establishes methods and criteria for determining the suitability of the Yucca Mountain site for the location of a geologic repository
    - **Methods** guide the evaluation process to be used
    - **Criteria** define the characterizing traits relevant to assessing the performance of a geologic repository
  - Suitability is determined on the basis of the repository system being likely to meet the applicable radiation protection standards

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## Suitability Guidelines – Preclosure Method



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### Suitability Guidelines – Preclosure Criteria

- Evaluate preclosure suitability using these criteria:
  - Ability to contain radioactive material and limit releases
  - Ability to implement control and emergency systems to limits exposure to radiation
  - Ability to maintain a system and components to perform their intended safety functions
  - Ability to preserve the option to retrieve wastes during the preclosure period

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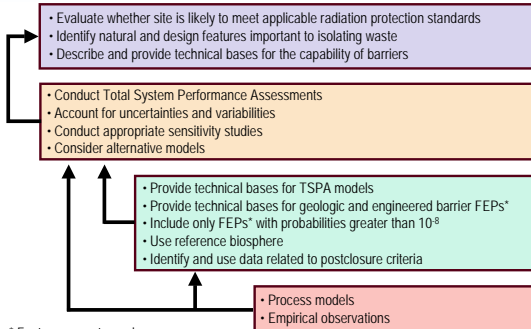
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### Suitability Guidelines – Postclosure Method



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### Postclosure Suitability Criteria – 1, 2

1. **Site characteristics, which include:**
  - Geologic properties of the site—for example, stratigraphy, rock type and physical properties, and structural characteristics;
  - Hydrologic properties of the site—for example, porosity, permeability, moisture content, saturation, and potentiometric characteristics;
  - Geophysical properties of the site—for example, densities, velocities and water contents, as measured or deduced from geophysical logs; and
  - Geochemical properties of the site—for example, precipitation, dissolution characteristics, and sorption properties of mineral and rock surfaces.
2. **Unsaturated zone flow characteristics, which include:**
  - Climate—for example, precipitation and postulated future climatic conditions;
  - Infiltration—for example, precipitation entering the mountain in excess of water returned to the atmosphere by evaporation and plant transpiration;
  - Unsaturated zone flux—for example, water movement through the pore spaces, or flowing along fractures or through perched water zones above the repository;
  - Seepage—for example, water dripping into the underground repository openings from the surrounding rock.

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### Postclosure Suitability Criteria - 3, 4, 5

**3. Near field environment characteristics, which include:**

- Thermal hydrology—for example, effects of heat from the waste on water flow through the site, and the temperature and humidity at the engineered barriers; and
- Near field geochemical environment—for example, the chemical reactions and products resulting from water contacting the waste and the engineered barrier materials.

**4. Engineered barrier system degradation characteristics, which include:**

- Engineered barrier system component performance—for example, drip shields, backfill, coatings, or chemical modifications, and
- Waste package degradation—for example, the corrosion of the waste package materials within the near-field environment.

**5. Waste form degradation characteristics, which include:**

- Cladding degradation—for example, corrosion or break-down of the cladding on the spent fuel pellets; and
- Waste form dissolution—for example, the ability of individual radionuclides to dissolve in water penetrating breached waste packages.

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### Postclosure Suitability Criteria – 6, 7

**6. Engineered barrier system degradation, flow, and transport characteristics, which include:**

- Colloid formation and stability—for example, the formation of colloidal particles and the ability of radionuclides to adhere to these particles as they may migrate through the remaining barriers; and
- Engineered barrier transport—for example, the movement of radionuclides dissolved in water or adhering to colloidal particles to be transported through the remaining engineered barriers and in the underlying unsaturated zone.

**7. Unsaturated zone flow and transport characteristics, which include:**

- Unsaturated zone transport—for example, the movement of water with dissolved radionuclides or colloidal particles through the unsaturated zone underlying the repository, including retardation mechanisms such as sorption on rock or mineral surfaces;
- Thermal hydrology—for example, effects of heat from the waste on water flow through the site.

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### Postclosure Suitability Criteria – 8, 9

**8. Saturated zone flow and transport characteristics, which include:**

- Saturated zone transport—for example, the movement of water with dissolved radionuclides or colloidal particles through the saturated zone underlying and beyond the repository, including retardation mechanisms such as sorption on rock or mineral surfaces; and
- Dilution—for example, diffusion of radionuclides into pore spaces, dispersion of radionuclides along flow paths, and mixing with non-contaminated ground water.

**9. Biosphere characteristics, which include:**

- Reference biosphere and reasonably maximally exposed individual—for example, biosphere water pathways, location and behavior of reasonably maximally exposed individual; and
- Biosphere transport and uptake—for example, the consumption of ground or surface waters through direct extraction or agriculture, including mixing with non-contaminated waters and exposure to contaminated agricultural products.

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## Postclosure Suitability Criteria - 10

### 10. Disruptive Events

- Volcanism—for example, the probability and potential consequences of a volcanic eruption intersecting the repository;
- Seismic events—for example, the probability and potential consequences of an earthquake on the underground facilities or hydrologic system; and
- Nuclear criticality—for example, the probability and potential consequences of a self-sustaining nuclear reaction as a result of chemical or physical processes affecting the waste either in or after release from breached waste packages.

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## Framework for Site Recommendation

- More than twenty years of scientific investigations related to
  - Site characterization (testing and analyses of the natural and engineered systems)
  - Development of conceptual repository and waste package designs
- Numerous technical documents reporting on the information gained from site characterization
- Regulatory framework
  - Environmental Protection Agency's (EPA) radiation protection standards (40 CFR 197)
  - Nuclear Regulatory Commission's (NRC) licensing requirements (10 CFR 63)
  - DOE's site suitability guidelines (10 CFR 963)

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## The Scientific Basis to Support a National Decision



Directly characterizing the repository block



Conducting laboratory tests



Conducting surface-based testing



Studying analogues



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### Preparation for Site Recommendation

- In December 1998, the DOE issued the **Viability Assessment**, a comprehensive and integrated snapshot of the understanding of the site at that time:
  - identified no "showstoppers"
  - laid out a plan for the work needed to complete site characterization and to submit a license application to the NRC
  - recommended that work should proceed at Yucca Mountain
- In May 2001, the DOE issued, for public comment:
  - Yucca Mountain Science and Engineering Report
    - Summarized the scientific and technical information developed through the characterization and design studies of the site
  - Yucca Mountain Preliminary Site Suitability Analysis,
  - Draft Environmental Impact Statement

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### Preparation for Site Recommendation (cont.)

- The Site Recommendation was a decision to proceed to the next step – submitting a License Application to the NRC
- The NWPA assigned responsibility for this decision to the Secretary of Energy
- The Secretary of Energy considered a significant amount of technical information prior to making the Site Recommendation.
  - The recommendation was supported by numerous independent peer reviews, and the program scientists
  - There was an International Peer Review of the Yucca Mountain TSPA with significantly different conclusions from those of the NWTRB
  - The Secretary was briefed and aware of the issues raised by the NWTRB
    - Realism in models; validation for use in licensing
  - The NRC agreed that supporting information was sufficient for inclusion in a license application

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### Site Recommendation

- Jan. 10, 2002 Secretary Abraham notified Governor Guinn of intent to recommend the Yucca Mountain site to the President
- Feb. 14, 2002 Secretary Abraham's **Recommendation and Comprehensive Basis for a Site Recommendation** were submitted to President Bush and made available to the public
- Feb. 15, 2002 President Bush approved Secretary's recommendation and submits it to Congress (publicly available), together with
  - Revised Science and Engineering Report,
  - Yucca Mountain Site Suitability Evaluation, and
  - Final Environmental Impact Statement
- April 8, 2002 Governor Guinn submitted Notice of Disapproval to Congress
- May 8, 2002 US House overrode governor's Notice of Disapproval
- July 9, 2002 US Senate overrode governor's Notice of Disapproval
- July 23, 2002 President Bush signed **Congressional Resolution** approving Yucca Mountain, allowing the project to proceed to the next step of license application

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